INTERTECH ENGINEERING CORPORATION

DEVELOPMENT AND DESIGN OF A PEAT FUEL DRYING SYSTEM

RENEWABLE ENERGY BRANCH

PREPARED FOR:

Renewable Energy Branch
Energy, Mines and Resources Canada
Ottawa, Canada

DSS Contract File No. 51SZ-23283-7-6063

November 1988

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FINAL REPORT

1. FRONT SECTION

1.1 TITLE

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1.4 PREFACE

The purpose of the work is to design and develop an economic and energy efficient industrial dryer for moisture content reduction of mechanically dewatered peat fuel to the point where the fuel would be an acceptable alternative to imported coal.

The design requires sufficient detail and depth to obtain accurate capital and operating costs in order to optimize both size and production capacities.

The scope of the work involved a dryer which could reduce the moisture content of peat fuel from 50% to 10% at a production rate of 250,000 tonnes of anhydrous peat/yr. The dryer would become part of a peat fuel processing system which would function in an outdoor atmosphere on a year-round basis. Reduction of the moisture content would raise the calorific value of the peat fuel to between 23,000 and 28,000 kJ/kg, (10,000 and 12,000 Btu/lb).

The significance of this work can best be explained in the following way.

- Ontario imports approximately 19 million tonnes of coal annually. There are sufficient known reserves of peat in the Thunder Bay area of Ontario to provide 50 million tonnes of dried peat yearly.

- The National Research Council has developed two important technical elements for year-round wet mining processing of peat.

  These are:

  (a) A centrifugal pump with integral macerator on the suction side to pump peat slurries directly from the peat bog to a process plant.

  (b) A dewatering process utilizing high velocity hydraulic forces to shear the colloidal structure of the peat in slurry form and so release the colloidally bound water. This process will reduce the water content of the peat from approximately 90% in slurry form to approximately 50% in a cake form from which pellets can be formed. Further drying is required if the pellets are to be used as fuel.

1.4 Preface cont.

Successful utilization of the Canadian peat reserves to provide a low cost alternative to imported coal depends upon:

(a) a year-round operating process;

(b) utilization of the NRC developed pump/macerator unit with the low severity dewatering process, as these together can produce 50% moisture peat for less than $28/tonne;*

(c) development of a low cost thermally efficient dryer for peat pellets with processing costs less than $10/tonne as an integral part of a total peat fuel processing system;

(d) development of markets for the processed peat pellet fuel. This market has been established.

- Benefits arising from the development and commercialization of the proposed dryer would be to provide:

  (a) lower costs compared to imported coal;
  (b) reduction of noxious gas emissions when burned;
  (c) creation of an industry with Canadian-developed technology;
  (d) job creation.

Those who would benefit most by the information developed in this project are organizations who intend to commercialize a peat fuel production industry in Canada as an alternative to imported coal.

Although some of the details of design are considered to be Intertech proprietary, the basic elements of the design are the direct result of EMR funding and as such are the property of the Government of Canada.

* A Low Severity Peat Dewatering Technology by E. Chornet et al. DSS Contract No. ISX79-00123.

1.5 ABSTRACT

A peat fuel drying system was designed to reduce the water content of peat fuel from 50% to 10% when operated as an integral component of a peat fuel processing system. The work was carried out under DSS Contract File No. 51SZ-23283-7-6063 for the Renewable Energy Programme of the Department of Energy, Mines and Resources.

The drying system is described as a horizontal, tunnel type, with flat belt conveyor, for outdoor operation, and with three distinct drying sections, namely: flue gas, warm air, and atmosphere. The wet peat fuel at 100°C (212°F) and 50% water, is initially dried with flue gas from the peat process system boiler at temperatures up to 260°C (500°F), then by warm air at 93°C (200°F) obtained from the condensing of wet steam in the process; and finally, by fresh air at 10°C (50°F), which together reduce the water content of the final peat product to 10% and with a temperature of 18.9°C (66°F).

The design of the drying system was modularized to give a production rate of 50,000 anhydrous tonnes of peat fuel/yr or 10,000 kg/hr (22,000 lbs/hr) from each of 5 units. In addition, the components of the system were modularized to reduce costs and ease of dismantling and erection for movement to alternate locations.

Detailed design and procurement drawings were prepared to obtain both capital and operating cost estimates. Based on the above, a 50,000 tonne/yr module has a capital cost of $400,000, and a drying cost of $0.375/1,000 MJ ($0.39/MBtu) of fuel processed, with heating energies of 23,000 kJ/kg (10,000 Btu/lb). The costs include depreciation, carrying charges, maintenance, energy, and labour.

Calculations of energy balance in the dryer show that for peat fuel entering the drying system with 50% water, the following conditions are obtained.

Item	Heat in 1,000 MJ/hr (MBtu/hr)			
	Entering Dryer		Leaving Dryer	
Peat Fuel, (incl.moisture)	5.82	(5.514)	0.057	(0.456)
Flue Gas	13.57	(12.861)	16.34	(15.485)
Hot Air	25.87	(24.52)	27.99	(26.528)
Cold Air	0.428	(0.406)	0.92	(0.872)
Totals =	45.7	(43.3)	45.7	(43.3)

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1.7 EXECUTIVE SUMMARY

Peat has long been used as a fuel source. Peat in the bog contains 90% water or more by weight and is difficult to transport and burn so that economic use of fuel peat depends upon dewatering. In general, the dewatering of peat has, until recently, been accomplished by excavation; spreading, and solar drying (the so-called conventional harvesting). This method is possible only during mild and reasonably dry weather thereby limiting its practicability.

Due to the collaborative efforts of NRC's Energy Division and the Laboratoire de Recherches sur les Technologies de Conversion (Université de Sherbrooke) a process has been recently developed for the removal of water from the peat which makes possible the concept of wet mining and thermomechanical treatment. The net result of this process is a modified peat material which can be mechanically dewatered into a cake having approximately 50% water.

The NRC/U de S approach has resulted in a new technological package which offers the following advantages over alternate methods:

- year-round operation even in cold climate;
- rapid processing;
- no major pollutants or sub products;
- low energy consumption.

This NRC/U de S system is described as a low severity process, that is, low temperature and pressure. If correctly applied to a total peat fuel processing plant it can be the means to economic production of peat fuel as a coal alternative.

However, in order for the dewatered peat to be useable as a fuel, further reduction in the water content is essential. In an extreme case, the water content should be reduced from 50% to 10% and this can be accomplished by the use of an energy efficient thermal drying system.

The work described in this report aims for the drying of peat fuel which has previously been wet mined and pressed after the low severity process noted above. In summary, the objectives of the work carried out in the project can be described as:

. design a thermal drying system to reduce the moisture content of peat fuel from 50% to 10% by utilizing waste thermal energy from other parts of a wet mining peat fuel process plant.

1.7 Executive Summary cont.

- optimization of the operating performance of the drying system to ensure economic use of energy.

The work was carried out by initially preparing several conceptual designs of drying systems and determining, by analysis, which of the concepts would best fit the objectives stated above. In addition, several methods of conveyance of the peat fuel within the dryer were investigated, most with respect to total costs. Though a clear distinction in methods did not evolve, the final design of the drying system allows for the use of either purely mechanical or pneumatic conveyance, or a combination of both.

In the final design, detailed drawings of the total system and major components were prepared in sufficient detail to determine accurate capital and operating costs, and also be used for any procurement.

Finally, the design of the drying system was optimized with respect to:

- overall size to ensure portability of major sections;
- modularizing the components;
- size of the various thermal drying sections to combine water removal with available amounts and types of waste thermal energy;
- total capital and operating costs.

The results of the work show that a peat fuel drying system module rated for handling 50,000 anhydrous tonnes of peat fuel/yr, with the entering fuel at a water content of 50% and a leaving water content of 10%, can be built for a capital cost of $400,000.00, and a drying cost, including depreciation, finance, maintenance, energy and labour, of the order of $0.375/1,000 MJ ($0.39/MBtu) of fuel produced, when using waste thermal energy from a peat fuel processing system.

Unit costs of energy for the system are based on a sliding scale of prices which depend upon the temperature of the gas and its average value to both the supplier and user system.

1.7 Executive Summary cont.

The highlights of this work are as follows:

- The planned drying system can accomplish water removal from previously mechanically dewatered peat fuel to a level of 10% or better, and at an exceptionally low energy cost.

- The planned drying system plays a vital role in a total peat fuel processing system in that it makes the production of a coal alternative economically feasible, well within the allowed economic limits for a thermal drying component.

Major conclusions of the work are that the drying system design is both economical and practical as a thermal energy integrated unit of a peat fuel processing system. In addition, the drying system utilizes existing and readily available components, materials, and technologies, and is operable in outdoor locations during the year-round climate conditions of northern Ontario or equivalent climate regions.

As a result the following recommendations are made.

- That Canada develop industries which either process the natural resources of Canada or use the processed natural resource products.

- The development of a thermal drying system as an integral energy using unit of a peat fuel processing system should be started without delay. This next step can be accomplished in many ways but it should result in the fabrication, testing, commissioning, and operation of a full size module.

- That the Federal Government of Canada continue the initiative of peat development in Canada by the development of specific hardware for the peat fuel processing industry, more specifically, mechanical and thermal dewatering, since these two items are crucial to the economic success of any large scale peat fuel production.

As project engineers and designers in this work, and from detailed involvement in the wet mining peat fuel processing using the NRC/U de S low severity system for conditioning the peat fuel slurry, it is evident that the importance of mechanical dewatering cannot be over stressed since collectively these two dewatering methods make it profitable to produce fuel peat by wet mining.

1.7 Executive Summary cont.

Presently, further collective effort by the private and public sectors is required, to prove, on a commercial scale, the successful efforts to date in peat fuel processing. Onshore low cost thermal energy is a major prerequisite to Canadian industrial growth. In addition, Canadian developed peat technology can be used for export.

1.8 RESUMÉ

2. CORE SECTION

2.1 INTRODUCTION

Published data accredits Canada with the world's largest peat resources estimated at approximately 170 million hectares (420 million acres). Of this, Ontario is estimated to have approximately 26 million hectares, of which about 9.9 million hectares, containing approximately 27 billion tonnes of peat fuel, are estimated to occur south of the permafrost. This is equivalent to about 46.6 billion barrels of oil or 10.8 billion tonnes of bituminous coal. Ontario imports some 19 million tonnes of coal per year, including about 16 million tonnes come from the United States and 3 million from western Canada at an estimated cost to the province of $1.6 billion. There are very substantial reserves of fuel peat in Ontario which may be mined and processed as an alternate fuel to displace the 19 million tonnes of coal imported into the province.

Peat has long been used as a fuel source. Fuel peat in the bog contains approximately 90% water by weight and, as such, is difficult to transport and burn. Economic development of fuel peat has always depended upon dewatering processes. Conventional harvesting which employs field drying is limited to having dry mild weather.

Year-round harvesting methods employing a wet mining (slurry) process are based upon hydraulic mining, followed by conditioning, pressing and thermal drying.

The wet mining peat fuel processing system has two basic functions, namely:

- To condition the wet (90% moisture) slurry by shearing the cells which hold water, so that dewatering can be carried out economically. This conditioning is performed by the low severity process which is based on a design by the NRC and the Université de Sherbrooke.

- To dewater the slurry after the "conditioning" process by mechanical and thermal processes. The proposed mechanical methods are by standard equipment, that is, screw, plate, or belt presses which can reduce the moisture content of the slurry from 90% to around 50%. Thereafter, the water removal is carried out by thermal means.

Basically then, the design and construction features of this modular thermal dewatering dryer are based on it being an integral part of the overall peat fuel processing system. As such, the dryer uses "used" energy, that is, flue gas and warm air from other parts of the processing system. In this way the proposed design is not a "stand alone" drying system. The drying costs are reduced by using waste energy from the slurry pre-treatment system.

2.2 OBJECTIVES

- To design an industrial type drying system for reduction of water in peat fuel, as obtained in a wet mining peat processing facility.
- To design a dryer module which will reduce the water content of peat fuel from 50% to 10%.
- To develop a drying system design for peat fuel which will be an integral part of a peat fuel processing system - physically, economically and thermally.
- To efficiently utilize the waste heat of a peat fuel processing system.
- To develop a dryer design which will be both modular in construction and portable.
- To optimize the drying system design to provide low cost drying of peat pellets under varying conditions.
- To prepare drawings and specifications of the dryer design in sufficient detail in order to determine both capital and operating costs to estimate the cost of drying peat per unit of energy.

2.3 DESIGN

2.3.1 General

To understand the basis of the design selection, reference should be made to the proposed peat fuel processing system. The attached Peat Fuel Process Flow Diagram, Figure #1, and Peat Fuel Process Elements, Table #1, show where and how the dryer becomes an integral part of the total system. In the peat fuel processing system a peat slurry with 90% water is first "conditioned" in the low severity section, then mechanically dewatered to approximately 50% water, and finally dried to 10% water by the horizontal tunnel dryer which is the subject of this project.

The type of dryer which evolved as a result of the above considerations can best be described as a horizontal, tunnel type, with three distinct drying sections, with a combination fluidized bed/moving belt type conveyor. The three sections of the dryer are called:

- Flue Gas Section - This is at the front end and uses 260°C (500°F) flue gas from a boiler which produces steam for the U de S/NRC peat fuel conditioning process.

- Hot Air Section - Refer to the Peat Fuel Process Flow Diagram, Figure #1. Atmospheric air is warmed up in a condenser where saturated steam is condensed.

- Cooldown Section - Atmospheric air is blown through the peat fuel to cool down the peat just prior to leaving the dryer.

2.3.2 Description of the Drying System

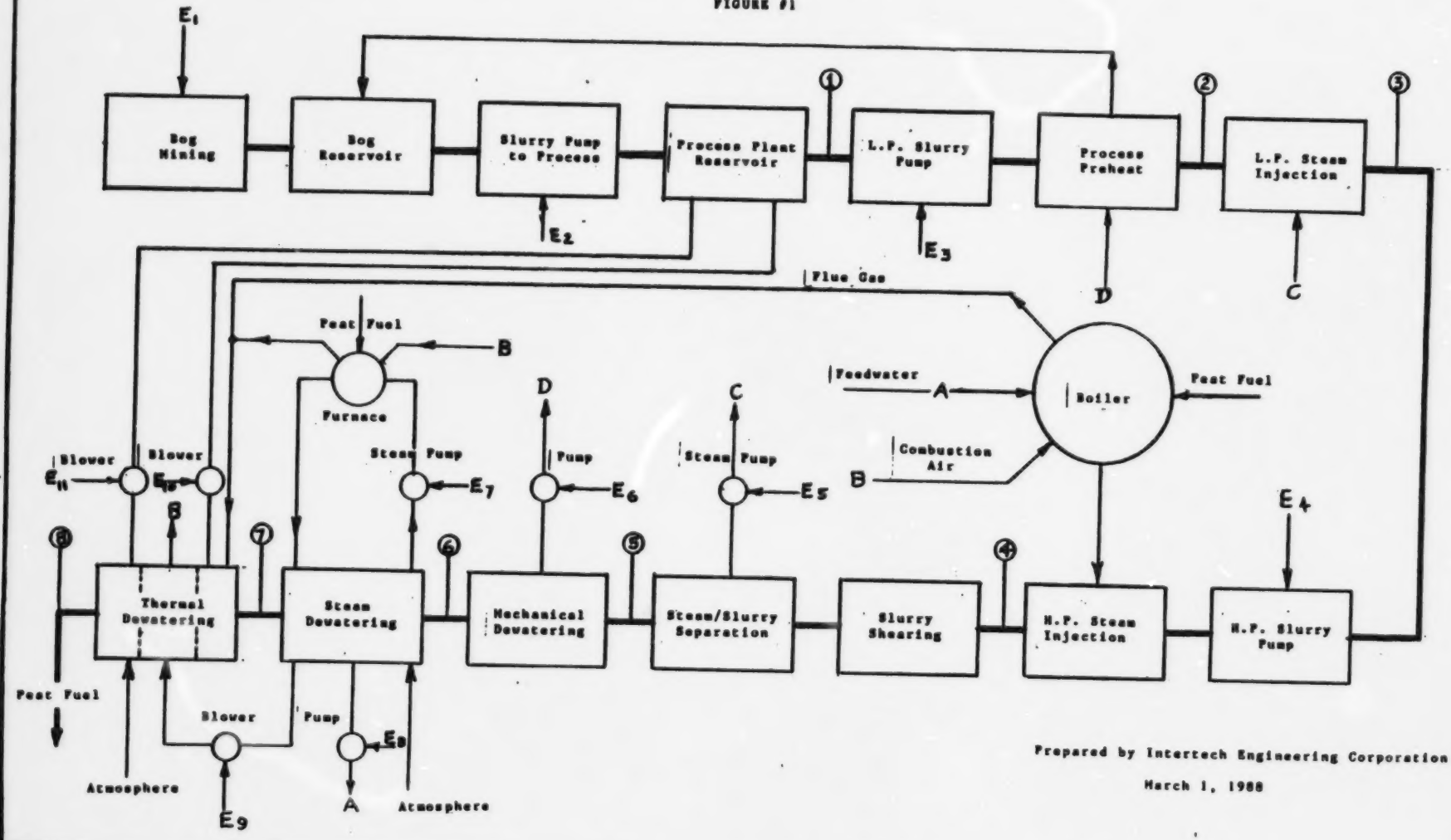
Reference should be made to the Peat Fuel Process Flow Diagram, Figure #1, and the typical cross-section of the peat fuel dryer shown in Figure #2.

The drying system is an integral part of the wet mining peat fuel processing plant where it is called the thermal dewatering unit along with possible use of a steam pre-dryer, which is not part of this project.

The drying system is described as a horizontal tunnel type, with a belt type conveyor and is composed of three drying sections, namely, flue gas, hot air, and cooldown. The peat fuel enters the drying system with a moisture content of 50% and leaves the drying system with an average moisture content of 10%. The peat fuel enters the dryer with a dry bulb temperature of approximately 94°C (200°F) and leaves at approximately 19°C (66°F).

PEAT FUEL PROCESS FLOW DIAGRAM

FIGURE #1



Prepared by Intertech Engineering Corporation

March 1, 1988

PEAT FUEL PROCESS ELEMENTS

TABLE #1

Wet Mining at the Bogsite with
NRC Developed Pump/Macerator

•
•

Bog Storage Facility

•
•

Slurry Transportation

•
•

Process Storage Tank
Water Solids Control

•
•

Low Pressure Pumps

•
•

Process Preheat Facility
Air Heat Exchangers
Water Heat Exchangers

•
•

Low Severity Processing Plant including:
Intermediate Pressure Pumps
Steam Injection
High Pressure Pumps
Boilers
Reactors
Homogenization
Disentrainers

•
•

Mechanical Dewatering

•
•

Agglomerator

•
•

Thermal Dewatering via:
Steam Dryer + Condenser (Optional)
Flue Gas Section of Dryer
Hot Air Section of Dryer
Cooldown Section of Dryer

•
•

Fuel to Customer

2.3.2 Description of the Drying System cont.

A fluidized bed conveyor, or a conventional woven (mesh) belt type can be used in the operation of the dryer.

The dryer design is modular in construction, and has a nominal rating of 50,000 anhydrous tonnes of peat fuel/yr. The concept of modularization has been carried throughout the entire structure of the dryer, in order to minimize costs and reduce site construction time.

Starting with the structural framework which supports the drying zone including conveyor, there are four U frames equally spaced from which the drying zone is hung. This arrangement caters to misalignment and thermal expansion and in addition allows the thermal isolation of the drying zone to minimize heat losses.

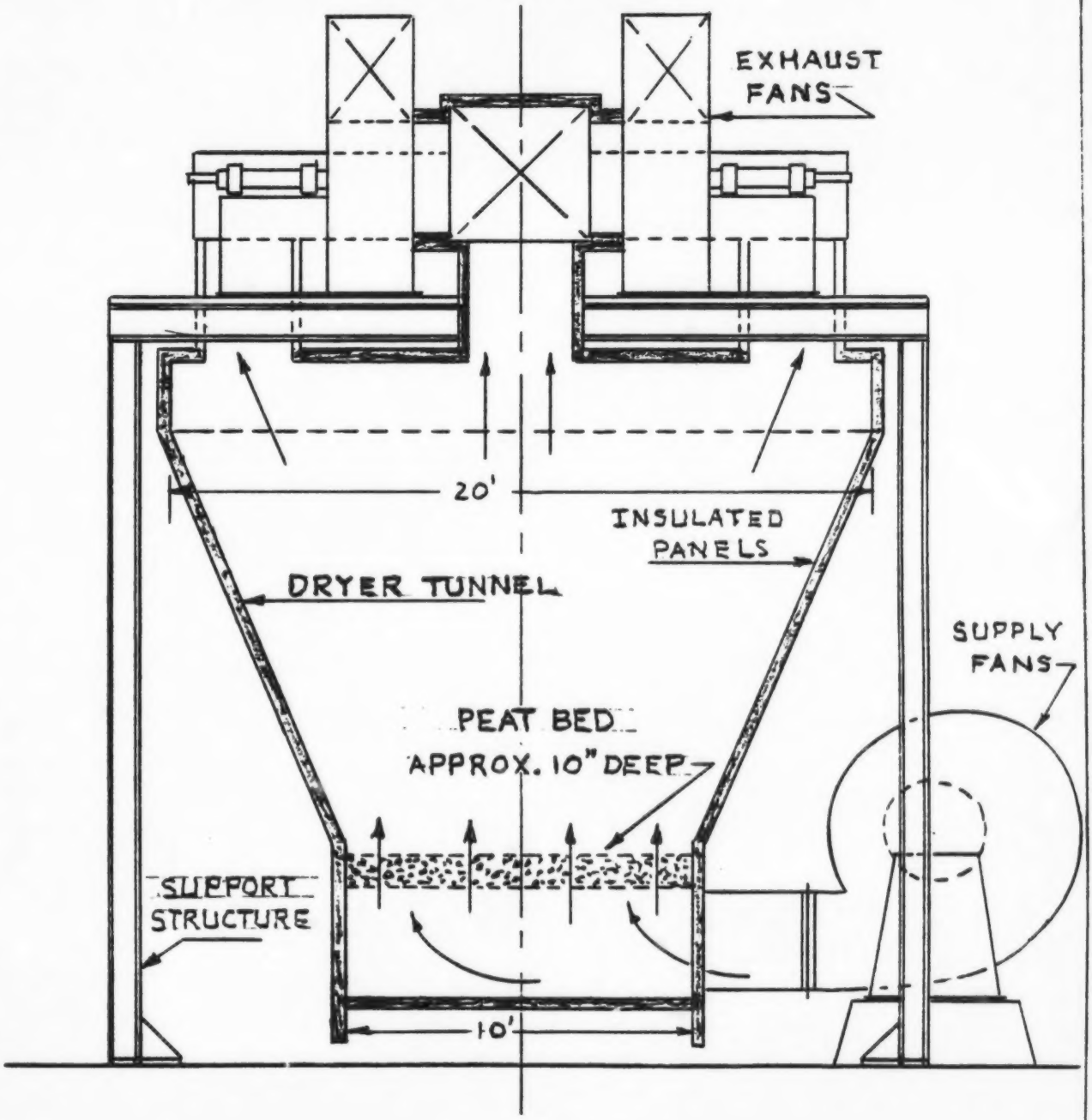
In cross-section, all drying zones are shaped such that the incoming drying atmospheres (i.e., flue gas, hot air, or ambient air) enter at a plenum below the conveyor, and are forced upwards through the conveyor and peat. This velocity will partially fluidize the peat. Near the top of the drying sections the average velocity is reduced by over half. A cyclone dust collector will be added later if it is needed.

Each drying zone is equipped with supply and exhaust fans. Exhaust fans are located atop the structure and isolated by cedar planking for vibration and thermal purposes. Supply fans are located on ground- supported concrete pedestals with flexible connections to the appropriate lower plenum of the drying system.

Ratings and quantities of the various fans are given in the general arrangement drawing.

Walls of the drying zones or dryer tunnel are made from metal clad sandwich type panels with Marinite insulation. Each panel has a standard width of 76cm (30 in.), with varying lengths. The joints between panels are gasketed to ensure leak tightness. All non metallic materials, that is, insulation, gaskets, etc., have been selected for high temperature service. The tunnel wall panels are structurally capable of supporting the conveyor plus peat loadings so that the drying tunnel will hang from the horizontal I beams of the support structure and be isolated from the ground.

TYPICAL CROSS SECTION
PEAT FUEL DRYER
FIGURE # 2



2.3.2 Description of the Drying System cont.

Regarding the three main sections of the drying tunnel, each of the zones is partially sealed from the next, so that these zones act as independent dryers but connected in series by a common structure. The exhaust temperatures from each zone are different and therefore used in differing preheat sections of the peat processing facility. All of the exhaust energy is utilized within the peat processing facility.

2.3.3 Design Details

Quantities and Types of Atmospheres Used for Drying

Three different considerations act simultaneously to limit the minimum quantity of gas needed for drying. These are:

- energy transfer - quantity of sensible heat transferred from the hot gas, in the intended temperature range;
- mass transfer - quantity of gas needed to carry the evaporation at the expected leaving temperature;
- diffusivity - time needed for moisture to migrate from the interior of particles to the surface for evaporation.

Energy Transfer

Where a high temperature for the gas is used, there are the following advantages for the dryer:

- a reduction in the size of the dryer and related auxiliary equipment such as fans, for a given moisture capacity;
- increased efficiency of energy use, obtained by converting a greater proportion of the total energy into latent energy.

Mass Transfer

The saturation humidity level for the carrying gas at its leaving temperature governs the amount of temperature drop which can be used in a dryer. Although an infinitely thick drying bed would be needed to reach saturation, the relative humidity rises close to 100% in 8cm. The planned dryer will have a thicker bed to reduce the chance of by-passing.

2.3.3 Design Details cont.

A relationship has been developed between the energy transfer and the mass transfer for drying, with 260°C (500°F) flue gas, and 93°C (200°F) warm air, as a function of leaving temperature. These are shown in Figure #3 and Figure #4 where these curves cross. The amount of gas needed for removing each unit of water from the peat can be determined at any value above the intersection of the two curves. The minimum gas requirement will be close to the point where the two curves intersect, i.e., greater than 11 kg gas/kg of water vapour evaporated by 260°C (500°F) gas.

Diffusivity

The rate at which moisture migrates to the surface of the product is more complicated than the energy or mass transfer. The general principles are simple enough:

- speed of moisture transfer increases at increased temperature;
- speed decreases at reduced moisture content;
- speed varies with differences in physical features of the product, including particle size, shape, porosity and chemical composition.

If the rates of heat transfer and mass transfer prove to be slower than desired, this can be compensated by increasing the quantity of peat in the dryer, or by using smaller pellets.

Effects of Fundamentals on Dryer Design

Most dryers use high temperatures for rapid drying with minimum flow rates. However, since the planned dryer will be associated with a pretreatment plant, which we call the "dewatering system," there are two special considerations which make intermediate temperature drying relatively attractive:

- production of low pressure warm air from the condensing of waste steam and hot flue gas in the dewatering system, will supply waste energy for drying;
- the quantities of still lower grade energy from the dryer are needed for bottom level heating of the peat slurry, including ice prevention in the slurry reservoir.

2.3.3 Design Details cont.

Flue Gas Temperatures

Although flue gas can be taken from a boiler at temperatures as low as 150°C (302°F), this requires exchangers in the boiler for preheating the feedwater and combustion air. With this dewatering system it is planned to use a relatively simple boiler: the feedwater will be some of the already hot condensate and the combustion air will be pre-heated in the dryer. Consequently, the flue gas will be delivered to the dryer at close to 260°C (500°F).

Quantity of Air Needed for Drying Peat

The following table is derived from psychrometric tables in ASHRAE. It uses the values for humidity ratio, Ws, at various leaving temperatures. From a base of 10°C (50°F), the differences in Ws at various temperatures are converted into masses of air and then volumes of air.

Temp°C	(Temp°F)	Ws	Difference in Ws Compared to 10°C (50°F)	Ratio Mass of Air/ Mass of Water at Stated Temp.
10.0	50	0.00765	--	--
10.4	51	0.00795	0.0003	3333.0
11.1	52	0.00826	0.0006	1667.0
12.8	55	0.00923	0.0016	625.0
15.6	60	0.01108	0.0034	294.0
18.3	65	0.01326	0.0055	182.0
21.1	70	0.01582	0.0081	123.0
26.7	80	0.02233	0.0147	68.0
32.2	90	0.03118	0.0235	42.0
37.8	100	0.04319	0.0355	28.0
48.9	120	0.08149	0.0738	14.0
60.0	140	0.1534	0.1457	6.8
71.1	160	0.2990	0.2837	3.5
82.2	180	0.6578	0.6501	1.5
87.8	190	1.099	1.091	0.917
93.3	200	2.295	2.287	0.437

Note:

Ws = Mass ratio of water vapour/dry air at saturation.

2.3.3 Design Details cont.

Conclusions from Quantity of Air Needed to Dry Peat

The main deterrent to cold drying is the large flow of air needed to scavenge the water vapour from the product being dried.

The humidity of the air being used for drying has a big effect on the quantity of air needed for drying, especially in systems where there is no heat supplied.

Where cold air and evaporation are cooling a hot product, the leaving air will be at a higher temperature than the entering air in most cases but can be at a lower temperature if the initial relative humidity was low and the product was not very hot.

Time Needed to Dry Peat

Other things being equal, drying time depends on the thickness of the bed of peat. The dryer can have a thin layer of peat going through it quickly, or a thicker layer moving more slowly. In either case, the amount of water removed each hour should be nearly the same, and the amount of peat dried should be nearly the same: these depend on other factors.

However, minor differences will occur because thickness of the active drying area, (mass transfer zone) is a fuzzy concept. The thickness of the bed of peat has to be greater than the mass transfer length in order to convert all of the superheat of the air into vapour.

Any papers which have been reviewed, referring to the determination of the mass transfer zone, show ways to find it by temperature observations in a working system, rather than by calculations made in advance. Some of the factors which can be expected to affect the length of a mass transfer zone include:

- particle size and shape
- air velocity
- air temperature
- air relative humidity
- product temperature.

Although these factors can affect the length of the mass transfer zone, this length actually does not seem to vary by much and is about 7.5 cm for materials like tree chips, or corn, or peat pellets. To prevent the danger of air by-passing the peat at thin spots in the bed, a thickness considerably greater than 15 cm is used, along with relatively small pellets.

2.3.3 Design Details cont.

If the peat pellets have a bulk density of 320 kg/cu.m. (20 lbs/cu.ft.), then the hourly throughput needed is 31 cu.m.(1,100 cu.ft.). When the thickness of the peat is at the planned maximum of 30 cm (1 ft.), there is 14 cu.m. (500 cu.ft.) of peat in the dryer at a time, thus requiring 2.2 loads/hr and a drying time of 27.3 minutes. At a minimum thickness of 15 cm (6 in.), drying time is shortened to 13.6 minutes. This is slow compared to a drying time of 1 minute in various high temperature dryers, but fast compared to a drying time of 1 month in a low temperature bin type dryer.

Hot Air Heated by Condenser Steam

There is more steam being produced in the peat process dewatering system than what is used for low pressure injection in the slurry heating. The excess will be condensed to supply hot air for a portion of the drying.

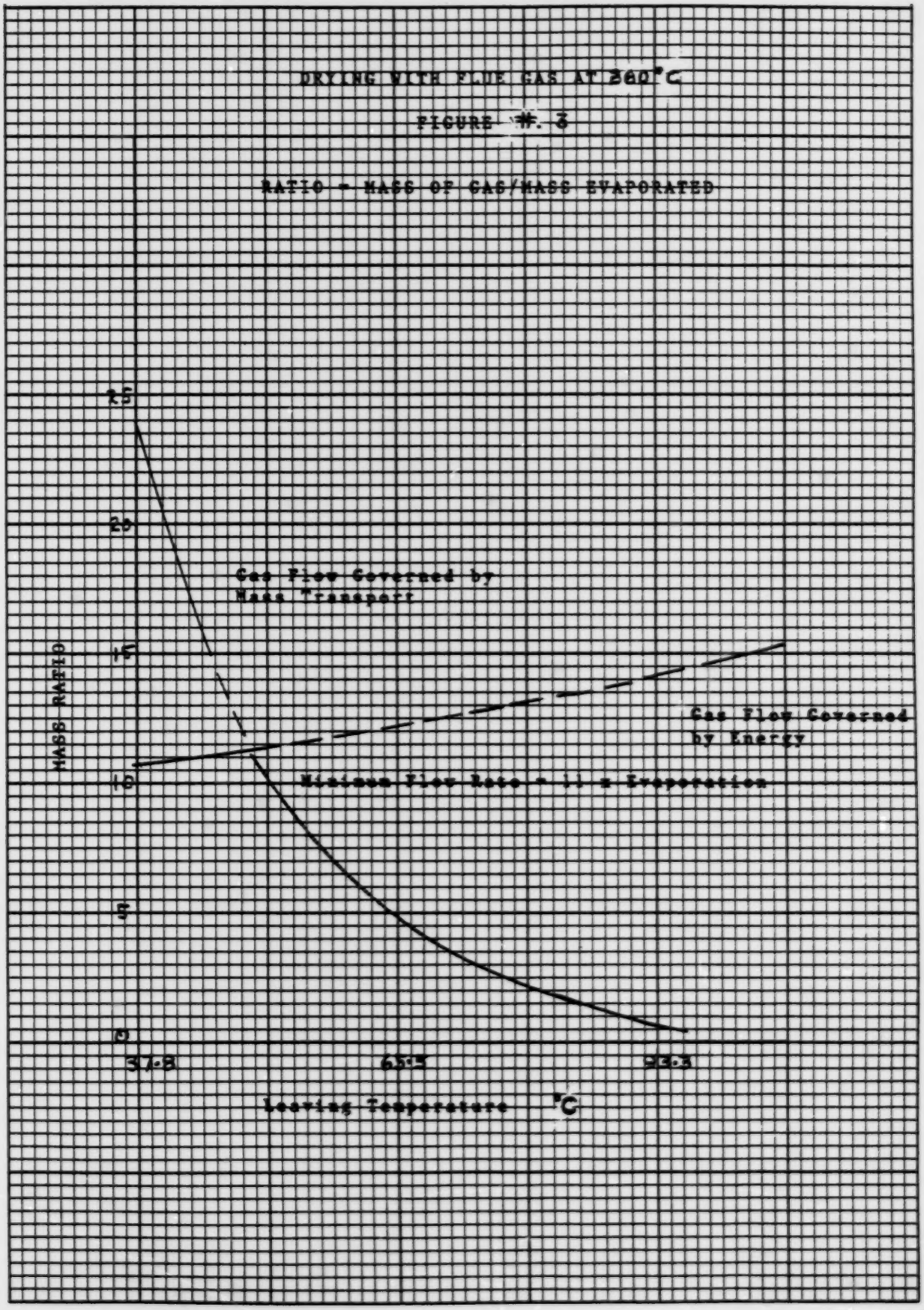
It takes 27 kg of cold air at 10°C (50°F) to absorb the heat from condensation of 1 kg of steam. 2/3 of this added heat can be used effectively in drying.

By then, the air is cooled to 38°C (100°F), but it has the same amount of energy as before, this energy being mostly in the form of water vapour. Although it is of no further use in drying, it is useful for freeze protection of the peat slurry.

When the heated air is cooled from 93°C (200°F) to 38°C (100°F) in the dryer, each kg of air supplies 55.8 kJ for evaporation, and it takes 44 kg of air to evaporate each kg of water. The total planned evaporation of 9,072 kg/hr (20,000 lbs/hr) would require 6,226 cu.m./min (220,000 cfm) of air at these conditions. Since part of the drying will be done with flue gas at a higher temperature, the actual air requirement is smaller.

Cooling of Dried Peat

The peat is cooled mainly by evaporation, rather than by conduction to a cold air stream. This evaporation is a significant part of the total drying. Cooling is important for increasing the strength and hardness of peat pellets. The quantity of air needed for cooldown varies with the moisture carrying capacity of the air.



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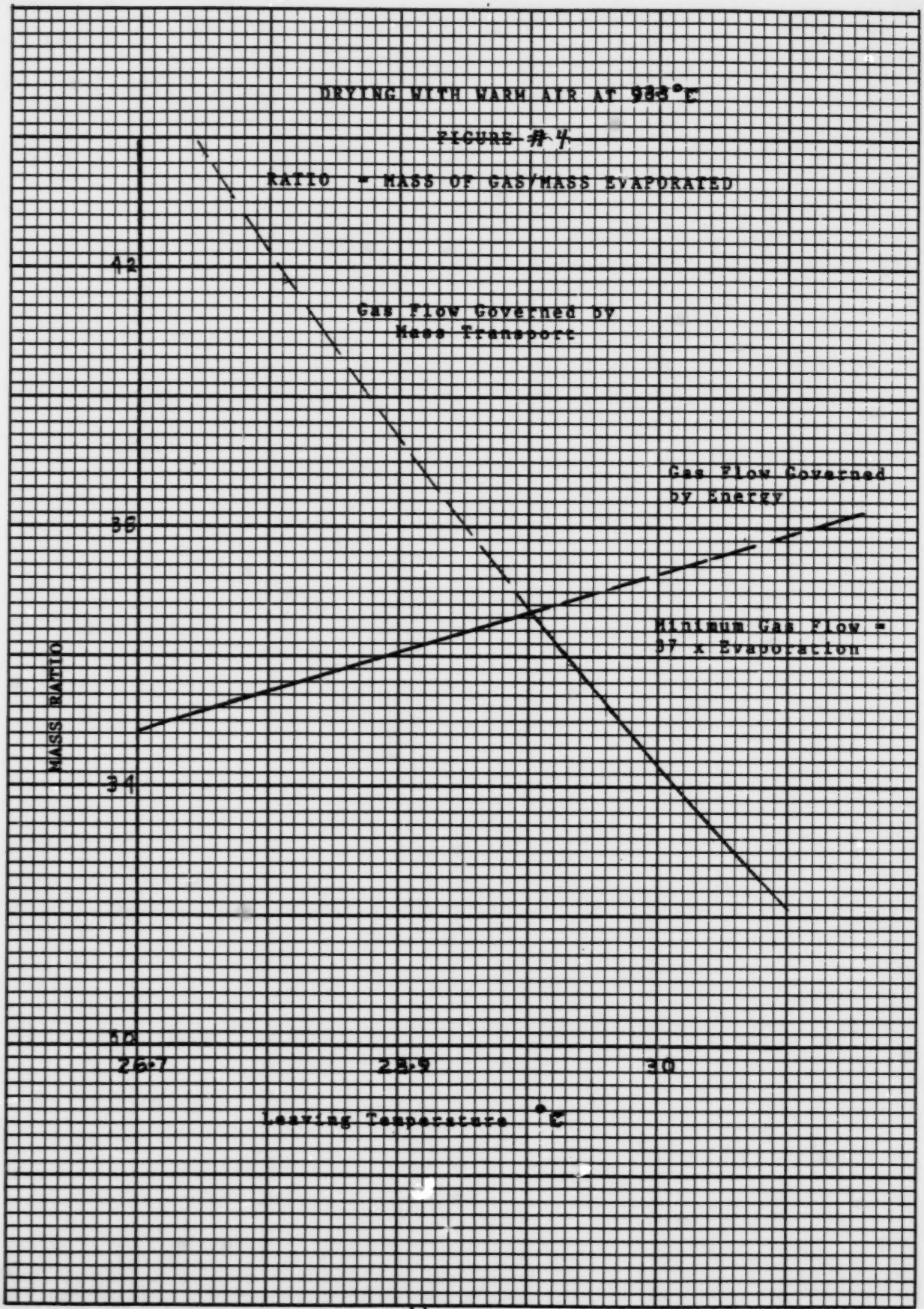
G-5 SQUARE 10 X 10 TO THE INCH



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2.3.3 Design Details cont.

Calculation of Process Numbers in a Peat Dewatering and Drying System

All of the numbers which follow are derived from the initial assumptions that:

- yearly production of finished peat = 50,000 tonnes dry basis in each dryer;
- operating hours = 5,000 hrs/yr;
- hourly production = 10 tonnes (22,000 lbs) dry weight;
- hourly evaporation = 9,072 kg (20,000 lbs).

Other assumptions will be mentioned where they are used in calculations.

2.3.4 Drawings

The following is a list of drawings prepared as part of this project in order to obtain accurate capital costs. These drawings are not included in this report due to space considerations, but can be obtained from Progress Report #3.

DRAWING NUMBER	DRAWING TITLE
IEC-PFP-GA-D-03	PEAT FUEL DRYER GENERAL ARRANGEMENT
IEC-PFP-OD-D-04	OUTLINE OF PEAT DRYER USING DIRECTIONAL FLUIDIZED BED METHOD OF CONVEYING PRODUCT
IEC-PFP-OD-D-05	OUTLINE OF PEAT DRYER WITH WIRE MESH CONVEYOR
IEC-PFP-DD-D-06	DETAILS OF SHEET METAL TUNNEL FOR DRYER
IEC-PFP-DD-A-10	DETAILS OF TUNNEL SUSPENSION THERMAL CONSIDERATIONS
IEC-PFP-DD-A-11	LOCATION OF TUNNEL SUSPENSION POINTS
IEC-PFP-SK-A-12	PERFORATED BED SKETCH
IEC-PFP-SK-A-13	SKETCH OF MESH BELT ON PERFORATED BED
IEC-PFP-DD-D-14	DETAILS OF SHEET METAL END FRAMES AND PARTITIONS FOR DRYER
IEC-PFP-DD-D-15	FLUID BED DECK
IEC-PFP-DD-D-16	DETAILS OF FLOOR PANELS FOR DRYER
IEC-PFP-DD-D-17	DETAILS OF INSULATION AND CLADDING FOR DRYER TUNNEL

2.3.5 Major Items

Purchased items, that is, blowers, fans, power control panel, conveyor, etc., but excluding minor hardware such as fasteners, are listed on the general assembly Drawing #IEC-PFP-GA-D-03 titled Peat Fuel Dryer General Arrangement, listed in Section 2.3.4.

All materials, that is, structural, etc., used in the fabrication of the sections of the tunnel plus the support structure are listed in the individual detail drawings.

2.3.6 Conveyors

The basic design of the dryer provides a choice between the use of two methods for conveying the peat.

- By fluidized bed only.
- By a combination of fluidized bed and mechanical conveyance, i.e., a moving belt.

Since the latter of these two options is the more costly, any estimates of capital and operating costs are based on this method of conveyor.

The combination of these two features dictates a long horizontal rectangular dryer. Another conveying method, vibratory conveying, was considered, but rejected because of the fragility of wet peat pellets.

Dust Carryover from Fluidized Dryer

If exhaust velocities are not low enough, the lighter particles of the peat will be carried from the system.

A large face area and a large volumetric capacity in the upper plenum to reduce the velocities by 50%, will reduce the carryover of dust. If necessary, external dust collectors will be added later.

Conclusions

- A regenerative dryer will have wide variations in its capacity and efficiency, making it important to have good operators and process controls.
- The maximum flow rate for air in a fluidized bed can be increased by up to 100%, by having outward sloped sidewalls in the upper plenum and a larger percentage hole area in the screen.

2.3.6 Conveyors cont.

- The dust carryover resulting from a high air flow rate can be reduced by having an enlarged upper plenum, with sloped walls to provide a gradation of velocities.

- For any given size of screen area a fluidized bed system will handle up to three times as much air as a non-fluidized system. This will require a dust collector.

- A large air flow rate is used in the present design concept because it uses secondary heat sources which result in reduced mass transfer per unit of air or gas.

- The planned dryer will be relatively large compared to hot dryers with similar mass transfer capabilities. Consequently, it is important to adopt relatively low cost construction using standard components. This counts against using a vibrating conveying system.

2.3.7 Instrumentation and Controls

The dryer does not require any automation or programming of the operation. All blowers and conveyor controls would be turned on manually from one control panel. In the normal operating mode, interlocks would require that the fan motors be "ON" while the conveyor is powered. All controls would be of the weatherproof class. Any instrumentation would be of the hand held variety to take spot measurements during operation in order to set or adjust such variables as flow rates of air and product.

2.3.8 Electrical Power

Sizes of the drive motors are such that 600 volt, 3 phase, 60 hertz electrical power would be the most practical and economic. All wiring, controls, motors, etc., would be of the weatherproof class, suitable for outdoor use in a year-round operation.

Any control power supplies would be single phase, 120 volt, 60 hertz, to minimize the risk of electrical shock to operating personnel.

2.3.9 Fabrication, Assembly, Testing

Refer to the drawings listed in this report. In general, the procedures used for fabrication and assembly are those normally found in sheet metal fabricating companies.

Testing, however, will require two categories:

(a) Purchased Items: these should be tested at the source of manufacturing to the appropriate MSS Specifications plus requirements of CSA in regard to electrical component safety.

(b) Assemblies: functional tests are required on the total assembly to ensure correct operation of components and other purchased items. Tests are also required to find flow rates of atmospheres at the various points on the dryer, and to eliminate leakage between the dryer tunnel and the atmosphere at jointed areas.

2.4 MASS AND ENERGY FLOW

2.4.1 Peat Fuel Processing System Conditions

Assumptions

- The slurry is taken as having an initial temperature of 10°C (50°F) at the process plant reservoir.
- The waste heat from the dryer provides the thermal energy to maintain the 10°C (50°F) temperature in the process reservoir during cooler temperatures, thus preventing freezing.
- The waste heat from dryer also provides warm combustion air for the boiler and furnace.
- Enthalpies for the slurry are taken as an equivalent enthalpy calculated as follows:
  hw = enthalpy of water
  hp = enthalpy of peat taken as 0.5 of water
  Gw = mass flow of water
  Gp = mass flow of peat
  Gs = mass flow of slurry.
  Then h = Gw x hw/Gs + Gp x hp/Gs where h = equivalent enthalpy of slurry.
- Temperature of slurry after hp steam injection is taken as 190°C (374°F).
- Pump energies are not considered in the calculations of heat energy.

References

Refer to the following information:
- Peat Fuel Process Flow Diagram - Figure #1
- Peat Fuel Process Elements - Table #1
- Mass Balance Summary - included
- Energy Balance Summary - included.

Process Plant Rating

- 250,000 anhydrous tonnes/yr
- Assume 5,000 operating hrs/yr
- 250,000/5,000 = 50 tonnes/hr
- 50,000 kg/hr (110,000 lbs/hr) dry peat.

Peat Fuel Product

- Assume 10% moisture
- Temperature of leaving product 19°C (66°F)
- Product production rate 54,440 kg/hr (122,222 lbs/hr)
- Water content 5,440 kg/hr (12,222 lbs/hr).

2.4.1 Peat Fuel Processing System Conditions cont.

Calculations - Mass and Energy Balance in Peat Slurry System Prior to Drying
- Refer to Peat Fuel Process Flow Diagram, Figure #1

Position #1 - (Cold Slurry Before Treatment)

Ts = 10°C (50°F)
Gs = 500,000 kg/hr (1.1 M lbs/hr)
Gw = 450,000 kg/hr (990,000 lbs/hr)
Gp = 50,000 kg/hr (110,000 lbs/hr)
hw = 42 kJ/kg (18.07 Btu/lb)
hp = 21 kJ/kg (9.0 Btu/lb)

Enthalpy of Wet Peat Slurry
h = 0.9 x 42 + 0.1 x 21 = 39.9 kJ/kg (17.16 Btu/lb)

Total Heat in Wet Peat
E = 500,000 x 39.9 = 19,950 MJ/hr (18.9 MBtu/hr)

Position #2 - (Raw Slurry, Preheated by Waste Heat)

Slurry after low severity treatment, before filtering

Assume: Gw = 450.000 kg/hr (990,000 lbs/hr)
Gp = 50,000 kg/hr (110,000 lbs/hr)
Gs = 500,000 kg/hr (1.1 M lbs/hr)
Ts = 93.3°C (200°F)

Peat in hot filter cake

Gw = 50,000 kg/hr (110,000 lbs/hr)
Gp = 50,000 kg/hr (110,000 lbs/hr)
Gs = 100,000 kg/hr (220,000 lbs/hr)
Ts = 93.3°C (200°F)

Amount of water removed by filtering = 450,000 - 50,000 = 400,000 kg/hr (880,000 lbs/hr)

h (Filter Inlet) = 391 x 0.9 + 195.5 x 0.1 = 371.4 kJ/kg (159.7 Btu/lb)

E (Filter Inlet) = 371.4 x 500,000 = 185,700 kJ/hr (176 MBtu/hr)

h (Filter Cake) = 391 x 0.5 + 195.5 x 0.5 = 293 kJ/kg (126 Btu/lb)

E (Filter Cake) = 293 x 100,000 = 29,300 MJ/hr (27.7 Mbtu/hr)

2.4.1 Peat Fuel Processing System Conditions cont.

Energy in hot water pressed out of peat

E = 185,700 - 29,300 = 156,400 kJ/hr (148 MBtu/hr)

Assume an HX efficiency of 0.85

Then energy transferred to slurry from hot water during preheat is: 156,400 x .85 = 132,940 kJ/hr (126 MBtu/hr)

In summary:

Position #2 - (Preheated Raw Slurry)

Heat in Cold Slurry = 19,908 MJ/hr (18.87 MBtu/hr)
Heat Added from Hot Water Exchangers = 132,719 MJ/hr (125.8 MBtu/hr)
Energy Flow at #2 = 152,627 MJ/hr (144.7 MBtu/hr)

Position #5 - (Processed Slurry, After Steam Disentrainment)

Gw = 450,000 kg/hr (990,000 lbs/hr)
Gp = 50,000 kg/hr (110,000 lbs/hr)
Gs = 500,000 kg/hr (1.1 M lbs/hr)
Ts = 93.3°C (200°F)
h = 0.9 x 391 + 0.1 x 195.5 = 371.45 kJ/kg (159.6 Btu/lb)
E = 371.45 x 500,000 = 185,725 MJ/hr (175.6 MBtu/hr)

Note: This energy is the same as after preheating, but subject to minor variations in temperatures.

Position #6 - (Filter Cake)

Gw = 50,000 kg/hr (110,000 lbs/hr)
Gp = 50,000 kg/hr (110,000 lbs/hr)
Gs = 100,000 kg/hr (220,000 lbs/hr)
Ts = 93.3°C (200°F)
h = .5 x 391 + 0.5 x 195.5 = 293 kJ/kg (126 Btu/lb)
E = 293 x 100,000 = 29,300 MJ/hr (27.7 MBtu/hr)

Position #4 - (Hot Slurry After High Pressure Steam Injection)

Planned temperature, 200°C (or 392°F) saturated
hw = 391 kJ/kg (168 Btu/lb)
hp = 195.5 kJ/kg (84 Btu/lb)
h (Steam) = 2,791 kJ/kg (1,200 Btu/lb)
Gw = 450,000 kg/hr (990,000 lb/hr)
Gp = 50,000 kg/hr (110,000 lbs/hr)
G (steam) = X

2.4.1 Peat Fuel Processing System Conditions cont.

Basis of Calculation

Previous total heat + steam heat = new total heat

152,627 MJ/hr + X x 2,791 kJ/kg = Gp x hp + Gw x hw + X x hw

X x (2,791 - 391) = 50,000 x 195.5 + 450,000 x 391

G (steam) = X = 77,400 kg/hr (170,000 lbs/hr)

E (steam) = 77,400 x 2,791 = 216,000 MJ/hr (204 MBtu/hr)

This mass of injected steam is removed later by evaporation in the disentrainer, at which point its enthalpy is 2,442 kJ/kg (1,050 Btu/lb). It will also have some superheat, to a maximum of 104 kJ/kg (50 Btu/lb), but probably half this amount, from evaporation occurring over a range of temperatures between 100°C and 200°C.

Position #8 - (Dried Peat from the Dryer Described in this Report)

Ts = 18.9°C (66°F)
Gs = 55,440 kg/hr (122,222 lbs/hr)
Gw = 5,440 kg/hr (12,222 lbs/hr)
Gp = 50,000 kg/hr (110,000 lbs/hr)
hw = 79 kJ/kg (34 Btu/lb)
hp = 39.5 kJ/kg (17 Btu/lb)
h = Gw x hw/Gs + Gp x hp/Gs = 0.1 x 79 + 0.9 x 39.5 = 43.45 kJ/kg (18.7 Btu/lb)
E = 43.45 kJ/kg x 55,440 kg/hr = 2,409 MJ/hr (2.28 MBtu/hr)

Position #7 - (Filtered or Pre-dried, 50% Moisture)

Ts = 93.3°C (200°F)
Gs = 100,000 kg/hr (220,000 lbs/hr)
Gw = 50,000 kg/hr (110,000 lbs/hr)
Gp = 50,000 kg/hr (110,000 lbs/hr)
hw = 391 kJ/kg (168 Btu/lb)
hp = 195.5 kJ/kg (84 Btu/lb)
h = 0.5 x 391 + 0.5 x 195.5 = 293 kJ/kg
E = 293 kJ/kg x 100,000 kg/hr = 29,300 MJ/hr (28 MBtu/hr)

Then E across thermal drying = (29,300 - 2,409) MJ/hr = 26,891 MJ/hr (25.5 MBtu/hr)

2.4.1 Peat Fuel Processing System Conditions cont.

MASS BALANCE SUMMARY
FOR A
250,000 TONNE/YR PEAT FUEL PROCESSING PLANT

FROM THE BOG

Peat	50 tonnes/hr	(110,000 lbs/hr)
Water	950 tonnes/hr	(2,090,000 lbs/hr)
Slurry	1,000 tonnes/hr	(2,200,000 lbs/hr)

ENTERING THE PROCESS

Peat	50 tonnes/hr	(110,000 lbs/hr)
Water	450 tonnes/hr	(990,000 lbs/hr)
Slurry	500 tonnes/hr	(1,100,000 lbs/hr)

LEAVING THE LOW SEVERITY SYSTEM

Peat	50 tonnes/hr	(110,000 lbs/hr)
Water	590 tonnes/hr	(1,299,790 lbs/hr)
Slurry	640 tonnes/hr	(1,409,790 lbs/hr)

ENTERING THE MECHANICAL DEWATERING SYSTEM

Peat	50 tonnes/hr	(110,000 lbs/hr)
Water	476 tonnes/hr	(1,050,000 lbs/hr)
Slurry	526 tonnes/hr	(1,160,000 lbs/hr)

ENTERING THE DRYER SYSTEM

Peat	50 tonnes/hr	(110,000 lbs/hr)
Water	50 tonnes/hr	(110,000 lbs/hr)
Slurry	100 tonnes/hr	(220,000 lbs/hr)

LEAVING THE PROCESS PLANT

Peat	50 tonnes/hr	(110,000 lbs/hr)
Water	5.5 tonnes/hr	(12,222 lbs/hr)
Slurry	55.5 tonnes/hr	(122,222 lbs/hr)

NOTE:Based on 5,000 hours operation/yr.

2.4.1 Peat Fuel Processing System Conditions cont.

ENERGY BALANCE SUMMARY
FOR A
250,000 TONNE/YR PEAT FUEL PROCESSING PLANT

FROM THE PROCESS PLANT RESERVOIR

Ts = 10°C (50°F)
Es = 19,950 MJ/hr (18.9 MBtu/hr)

AFTER PROCESS PREHEAT

Ts = 73.3°C (164°F)
Es = 152,600 MJ/hr (145 MBtu/hr)

AFTER STEAM INJECTION

Ts = 200°C (392°F)
Es = 368,600 MJ/hr (349 MBtu/hr)

ENTERING MECHANICAL DEWATERING SYSTEM

Ts = 93.3°C (200°F)
Es = 185,700 MJ/hr (175 MBtu/hr)

LEAVING MECHANICAL DEWATERING/ENTERING THERMAL DEWATERING

T(peat) = 93.3°C (200°F)
E = 29,300 MJ/hr (28 MBtu/hr)

LEAVING THERMAL DEWATERING SYSTEM

T = 18.9°C (66°F)
E = 2,380 MJ/hr (2.3 MBtu/hr)

2.4.2 Mass and Energy Balance for One 50,000 tonne/yr Dryer Module

Hot Flue Gas Section of Dryer (Figure #5)

Inlets to Section

Wet Peat Inlet - Position #1

Gp = 10,000 kg/hr (22,000 lbs/hr)
Gw = 10,000 kg/hr (22,000 lbs/hr)
t = 93.3°C (200°F)
hw = 391 kJ/kg (168 Btu/lb)
hp = 195.5 kJ/kg (84 Btu/lb)
Energy E = Gp x hp + Gw x hw = 10,000 x 195.5 + 10,000 x 391
= 5,865 MJ/hr (5.56 MBtu/hr)

Hot Gas Inlet - Position #2

temp. t = 260°C (500°F)
Gg = 33,113 kg/hr (73,000 lbs/hr)
assumed dewpoint = 37.8°C (100°F)
air sp.ht.= 1 kJ/kg/°C (0.24 Btu/lb/°F)
water vapour = 2.05 kJ/kg/°C (0.49 Btu/lb/°F)
humidity ratio of inlet gas = 0.04319 by weight
mass of vapour with the gas = Gv = 0.04319 x 33,113 kg/hr =
1,430 kg/hr
hv = 2,570 kJ/kg (at 37.8°C)
Ev Energy Flow (vap) = Gv x hv + Gv x (260 - 37.8) x 2.05 =
4,326 MJ/hr (4.1 MBtu/hr)

Dry Gas

hg enthalpy at 37.8°C = 55.9 kJ/kg
hg heat at 260°C = 55.9 + (260 - 37.8) x 1 = 278.1 kJ/kg
(120 Btu/lb)
Gg = 33,113 kg/hr (73,000 lbs/hr)
Eg = Energy flow = Gg x hg = 33,113 x 278.1 = 9,209 MJ/hr
(8.7 MBtu/hr)
E tot = sum of gas and vapour = Ev + Eg = 4,326 + 9,209 =
13,535 MJ/hr (12.8 MBtu/hr)

2.4.2 Mass and Energy Balance for One 50,000 tonne/yr Dryer Module cont.

Peat Conveyed Out of Flue Gas Section to Warm Air Section

shw = spec.ht.water = 1 x 1.055/.4536 x 9/5 = 4.1865 kJ/kg/hr/°C

shp = 2.093 kJ/kg/hr/°C

t = assumed temperature = 66°C (150°F)

Lp = loss of energy by cooling of peat = Gp x (93.3 - 66) x shp = 10,000 x 27.3 x 2.09 = 571 MJ/hr

Lw = loss of energy by cooling of water = Gw x (93.3 - 66) x shw = 10,000 x 27.3 x 4.1865 = 1,143 MJ/hr (1.08 MBtu/hr)

E evap = energy used in evaporation = heat from cooling of peat, water and gas = (571 + 1,143 + 7,012)MJ/hr = 8,726 MJ/hr (8.27 MBtu/hr)

heat of evaporation at 66°C = 2,344 kJ/kg

G evap = 8,726,000/2,344 = 3,723 kg/hr (8,263 lbs/hr)

Gw = remaining water in peat = 10,000 - 3,723 = 6,277 kg/hr

hw = enthalpy of water at 66°C = 274.4 kJ/kg

hp = 137.2 kJ/kg

E tot = energy in peat and water = 10,000 x 137.2 + 6,277 x 274.4 = 3,094 MJ/hr (2.933 MBtu/hr)

Used Gas Outlet from Dryer - Position #5

t = assumed temperature 66°C (150°F)

hg = enthalpy of dry gas at 66°C = 83.9 kJ/kg (36.063 Btu/lb)

Eg = energy in dry gas = Gg x hg = 33,113 x 83.9 = 2,778 MJ/hr (2.6 MBtu/hr)

hv = enthalpy of vapour at 66°C = 2,619 kJ/kg (from steam table)

Ev = heat in vapour = 1,430 kg/hr x 2,619 kJ/kg = 3,745 MJ/hr (3.55 MBtu/hr)

E tot = Eg + Ev = 2,778 + 3,745 = 6,523 MJ/hr (6.18 MBtu/hr)

L = loss in heat due to cooling = 13,535 - 6,523 = 7,012 MJ/hr

Gv = Gv + G evap = new mass of vapour = original + evap = (1,430 + 3,723)kg/hr = 5,153 kg/hr (11,360 lbs/hr)

Ev = energy = Gv x hv = 5,153 kg/hr x 2,619 kJ/kg = 13,496 MJ/hr (12.79 MBtu/hr)

Ea = add energy in dry gas = 2,778 MJ/hr

E = total energy in wet gas = 16,274 MJ/hr (15.4 MBtu/hr)

Enthalpy = 16,274 MJ/hr/33,113 kg/hr = 491 kJ/kg, which equals a saturation temperature of 60°C. This energy can be carried readily at the assumed temperature of 66°C.

2.4.2 Mass and Energy Balance for One 50,000 tonne/yr Dryer Module cont.

Warm Air Section of Dryer

Peat Inlet (Same as peat outlet from flue gas section.)

t = temperature t = 66°C (150°F)
Gp = mass of solids = 10,000 kg/hr (22,000 lbs/hr)
hp = 137.2 kJ/kg
Gw = mass of water = 6,278 kg/hr
hw = 274.4 kJ/kg
E = total energy = Gp x hp + Gw x hw = 3,094 MJ/hr

Warm Air Inlet - Position #3

assumed condition temperature t = 93.3°C (200°F)
dewpoint = 10°C (50°F)
Ga = mass flow Ga = 195,500 kg/hr (431,000 lbs/hr)
r = humidity ratio at 50°F dewpoint = 0.007658
Gv = mass of water vapour in air = Ga x r = 1,497 kg/hr
hv = enthalpy of water vapour at 93.3°C = 2,665 kJ/kg
(from steam table)
Ev = energy in vapour = Gv x hv = 1,497 x 2,665 =
3,990 MJ/hr (3.78 MBtu/hr)
ha = enthalpy of dry air at 93.3°C = 111.9 kJ/kg
Ea = energy in dry air = Ga x ha = 195,500 x 111.9 =
21,881 MJ/hr (20.74 MBtu/hr)
E tot = Ev + Ea = 3,990 + 21,881 = 25,871 MJ/hr
(24.52 MBtu/hr)

Peat Conveyed from Hot Air Section to Cooling Section

t = assumed temperature = 37.8°C (100°F)
hp = 79.1 kJ/kg
Ep = Gp x hp = 10,000 x 79.1 = 791 MJ/hr (750,000 Btu/hr)
hw = 158.2 kJ/kg
Gw = 6,278 kg/hr
Ew = Gw x hw = 6,278 x 158.2 = 993,200 kJ/hr
E tot = remaining energy in peat which entered section =
Ep + Ew = 791 + 993 = 1,784 MJ/hr (1.691 Mbtu/hr)
L = loss of energy by cooling = 3,094 - 1,784 = 1,310 MJ/hr
E evap = L + heat lost by warm air = 1,310 + 11,096 =
12,406 MJ/hr
he = heat of evaporation at 37.8°C = 2,411 MJ/kg
G evap = E evap/he = 12,406/2,411 = 5,146 kg/hr
Gw = Gw - G evap = 6,278 - 5,146 = 1,132 kg/hr
E = Gp x hp + Gp x hw = 10,000 x 79.1 + 1,132 x 158.2 =
970 MJ/hr

2.4.2 Mass and Energy Balance for One 50,000 tonne/yr Dryer Module cont.

Used Air Outlet - Position #6

assumed temperature t = 37.8°C (100°F)
hv = enthalpy of water vapour at 37.8°C = 2,570 kJ/kg
Ev = energy in original water vapour = 1,497 kg/hr x 2,570 kJ/kg = 3,847 MJ/hr
ha = enthalpy of dry air at 37.8°C = 55.9 kJ/kg
Ea = heat remaining in dry air = Ga x ha = 195,500 kg/hr x 55.9 kJ/kg = 10,928 MJ/hr (10.35 MBtu/hr
Et = total heat in original air = Ev + Ea = 3,847 + 10,928 = 14,775 MJ/hr (14.0 MBtu/hr)
E diff = heat lost by warm air = (25,871 - 14,775)MJ/hr (10.52 MBtu/hr)
Gv = new mass of water vapour = Gv + G evap = 1,497 + 5,146 = 6,643 kg/hr
Ev = energy in vapour = Gv x hv = 6,643 kg x 2,570 kJ/kg = 17,072 MJ/hr
E tot in exhaust = Ev + Ea = 17,072 + 10,928 = 28,000 MJ/hr

Cooling Section of Dryer

Peat Inlet (Same as peat outlet from warm air section.)

t = 37.8°C (100°F)
Gp = 10,000 kg/hr (22,000 lbs/hr)
hp = 79.1 kJ/hr (34.01 Btu/lb)
Gw = 1,132 kg/hr (2,496 lbs/hr)
hw = 158.2 kJ/kg (68.02 Btu/lb)
Ep = Gp x hp = 10,000 x 79.1 = 791 MJ/hr
Ew = Gw x hw = 1,132 x 158.2 = 179 MJ/hr
E tot = Ep x Ew = 970 MJ/hr

Ambient Air Inlet - Position #4

t = 10°C (50°F)
dewpoint = 10°C (50°F)
r (humidity ratio) = .007658
Ga (mass flow of dry air) = 9,072 kg/hr
hv (enthalpy of water vapour at 10°C) = 2,519 kJ/kg
Gv = Ga x r = 9,072 x .007658 = 69.47 kg/hr
Ev = Gv x hv = 69.47 x 2,519 = 175,000 MJ/hr (165,880 Btu/hr)
ha = enthalpy of dry air = 27.935 kJ/kg
Ea = Ga x ha = 9,072 x 27.935 = 253,400 MJ/hr (240,200 Btu/hr)
E = total energy = Ev + Ea = 175,000 + 253,400 = 428.4 MJ/hr (406,066 Btu/hr)

2.4.2 Mass and Energy Balance for One 50,000 tonne/yr Dryer Module cont.

Dry Peat in Cooling Section Outlet - Position #8

t = 18.9°C (66°F)
mass of peat Gp = 10,000 kg/hr (22,000 lbs/hr)
hp = 39.6 kJ/kg
mass of water Gw = 1,132 kg/hr (Entering cooling section.)
hw = 79.25 kJ/kg
E = Gp x hp + Gw x hw = 10,000 x 39.6 + 1,132 x 79.25 = 486 MJ/hr
E before this cooling = 970 MJ/hr
E evap = entering energy of peat - leaving energy of peat - gain in air by warming = 970 - 486 - 174 = 310 MJ/hr
h evap = heat of evaporation at 28.9°C = 2,433 kJ/kg
G evap = E evap/h evap = 310/2.433 = 127 kg/hr
Gw = 1,132 - 127 = 1,005 kg/hr (2,216 lbs/hr)
E = Gp x hp + Gw x hw = 10,000 x 39.6 + 1,005 x 79.25 = 476 MJ/hr
MC (Final moisture content) = Gw/(Gp + Gw) x 100
= 1,005/(10,000 + 1,005) x 100% = 9.1%,
which more than accomplishes the planned reduction to 10%

Waste Air Outlet - Position #7

t = 28.9°C (Is higher than peat leaving temperature due to 3-pass circulation.)
Ga = 9,072 kg/hr
ha = 47 kJ/kg (Enthalpy of dry air)
hv = 2,553 kJ/kg
Gv = 69.47 kg/hr (Vapour in entering air)
sp.ht. of dry air = 1 kJ/kg/°C
air energy gain = Ga x (28.9 - 10) x 1 = 171,461 kJ/hr
sp.ht. of water vapour = 2.04 kJ/kg/°C
vapour energy gain = Gv x (28.9 - 10) x 2.04 = 2,678 kJ/hr
E = total energy gain by warming = 171,461 + 2,678 = 174.14 MJ/hr
Add mass evaporated G evap = 126 kg/hr
Gv = Gv + G evap = 69.47 + 126 = 195 kg/hr
hv at 28.9°C = 2,554 kJ/kg
Ev = Gv x hv = 195 x 2,554 = 498,030 kJ/hr
Ea = Ga x ha = 9,072 x 47 = 426,384 kJ/hr
E = Ev + Ea = 924,414 kJ/hr
h = E/Ga = 924,414/9,072 = 102 kJ/kg. This corresponds to t = 26.7°C saturated, which can be carried by 28.9°C air.

2.4.2 Mass and Energy Balance for One 50,000 tonne/yr Dryer Module cont.

Totals for Whole Dryer

Mass Flows

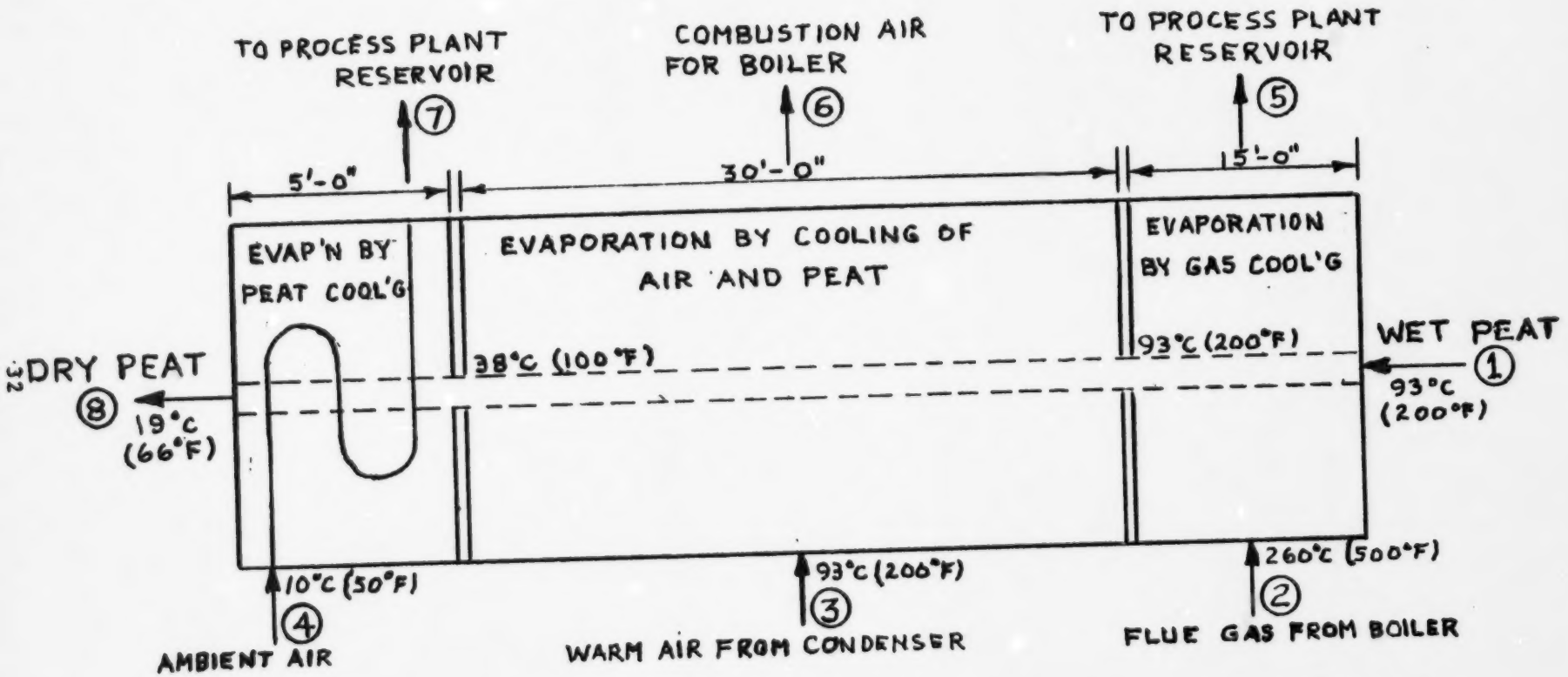
	Peat Solids kg/hr (lbs/hr)	Water incl.Vapour kg/hr (lbs/hr)	Dry Air incl.Flue Gas kg/hr (lbs/hr)
Inlet			
Wet Peat #1	10,000 (22,000)	10,000 (22,000)	---- ----
Flue Gas #2	---- ----	1,430 (3,153)	33,113 (73,000)
Hot Air #3	---- ----	1,497 (3,300)	195,500 (431,000)
Ambient Air #4	---- ---	69 (153)	9,072 (20,000)
Total =	10,000 (22,000)	12,996 (28,606)	237,685 (524,000)
Outlet			
Dry Peat #8	10,000 (22,000)	1,005 (2,216)	---- ----
Flue Gas #5	---- ----	5,153 (11,416)	33,113 (73,000)
Warm Air #6	---- ----	6,641 (14,639)	195,500 (431,000)
Cold Air #7	---- ----	195 (510)	9,072 (20,000)
Total =	10,000 (22,000)	12,994 (28,781)*	237,685 (524,000)

Energy Flows

Inlet		
Wet Peat #1	5.865 MJ/hr	(5.56 MBtu/hr)
Flue Gas #2	13.535 MJ/hr	(12.83 MBtu/hr)
Hot Air #3	25.871 MJ/hr	(24.52 MBtu/hr)
Ambient Air #4	.428 MJ/hr	(0.41 MBtu/hr)
Total =	45.699 MJ/hr	(43.3 MBtu/hr)
Outlet		
Dry Peat #8	.476 MJ/hr	(.40 MBtu/hr)
Flue Gas #5	16.274 MJ/hr	(15.4 MBtu/hr)
Warm Air #6	28.000 MJ/hr	(26.54 MBtu/hr)
Cold Air #7	.924 MJ/hr	(0.88 MBtu/hr)
Total =	45.674 MJ/hr	(43.2 MBtu/hr)

* Error in energy totals = 25 on 45,699 or 0.05%, due to rounding of numbers.

MASS AND ENERGY FLOW DIAGRAM
FIGURE # 5



NOTE: SEE MASS & ENERGY FLOW DATA SHEET FOR VALUES AT NUMBERED LOCATIONS

EMR-IEC PEAT FUEL DRYER.
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DATE: 88-01-29

2.5 ECONOMIC ASSESSMENT

2.5.1 Approach

Since the energy for thermal drying is taken from waste flue gas and waste steam from the peat slurry dewatering process, then the thermal energy costs for the drying system are highly dependent upon the costs established for these "waste" energies.

In order to establish a cost value for these thermal energies a method was developed which is detailed in Appendix C and titled:

"The Value of Waste Heat."

The values established in this Appendix are "user" costs and not "supplier" costs, which are quite different. Basically, the unit costs of energy used for determining the energy costs of the drying system are based on a sliding scale of prices, which in turn depend upon the temperature of the gas, and its average value, to both the supplier and user systems.

In determining the capital cost of a drying system module rated at 50,000 anhydrous tonnes of peat fuel/yr, these were obtained from two sources, namely:

- Manufacturers of specific pieces of equipment as obtained from the detailed drawings produced for this project.

- Fabricators of structural and sheet metal products who regularly carry out similar classes of work.

The above detailed approach to capital cost estimates, it was felt, would produce costs much closer to reality than any ballparking estimates based on volume, size, etc., for drying systems.

This design of a drying system is too unique to be estimated on the basis of similar equipment.

2.5.2 Cost Estimates

PEAT FUEL DRYER

CAPITAL COST ESTIMATE FOR A DRYER MODULE

RATED 50,000 TONNES/YR

TUNNEL ANGLE FRAMING		$19,360.00
TUNNEL ANGLE INTERNAL TRUSSES		$ 4,640.00
TUNNEL SHEETING		$34,720.00
TUNNEL END FRAME/SHEET		$ 6,800.00
TUNNEL INTERNAL PARTITIONS		$ 4,100.00
TUNNEL FLUIDIZING BED SHEETS		$ 9,000.00
TUNNEL GASKETING STRIPS		$ 5,200.00
TUNNEL INSULATION SPIN GLASS 650 (MANSON)		$ 3,300.00
TUNNEL INSULATION ALUMINUM COVER PANELLING		$26,100.00
SUB TOTAL =		$113,220.00
STEEL EQUIPMENT PLATFORM		$21,000.00
WOOD PLATFORM DECKING		$ 1,320.00
SUB TOTAL =		$22,320.00
DUCTING		$26,250.00
DUCTING INSULATION		$ 2,460.00
DUCTING INSULATION ALUMINUM COVERING		$15,000.00
CONTROL PANEL, WIRING INSTRUMENTATION		$25,000.00
SUB TOTAL =		$68,710.00
CONVEYOR DRIVE DRUM		$16,800.00
IDLER ROLLERS		$ 8,000.00
CONVEYOR MESH BELT		$ 5,760.00
SUB TOTAL =		$30,560.00
3-32,000 CFM SUPPLY FANS (#90 AW)	$23,000.00	$69,000.00
1-10,000 CFM SUPPLY FANS (#50 AW)	$ 5,000.00	$ 5,000.00
3-32,000 CFM EXHAUST FANS (#90 AW)	$23,000.00	$69,000.00
SUB TOTAL =		$143,000.00
LABOUR FOR SITE ASSEMBLY & COMMISSIONING =		$ 22,190.00
TOTAL =		$400,000.00

2.5.2 Cost Estimates cont.

Capital and Operating Costs for a 50,000 Tonne/Yr Tunnel Type Dryer Module as an Integral Part of the Peat Fuel Processing System where the Moisture Content is Reduced from 50% to 10%.

---

a) Capital Cost/Refer to detailed cost estimate...$400,000.00

b) Depreciation - Straight Line 20 year.....$ 20,000.00/yr

c) Carrying Cost - 10%.....$ 40,000.00/yr
1st year
Declining to $ 2,000.00 in final year
Avge $ 21,000.00/yr

d) Operating Cost

. Maintenance.....$ 15,000.00

. Energy Cost
- Flue Gas.....$ 37,221.00
- Warm Air.....$ 19,403.00
- Atmosphere.....$ 0
- Electrical Power.....$150,000.00

. Direct Labour - 1 man full time @ $24/hr.....$120,000.00

e) Total Annual Costs.....$382,624.00
Rounded to $383,000.00

f) Production 50,000 tonnes/yr x 20,440 kJ/kg x 1,000 kg/tonne
= 1,022,000,000 MJ/yr

(Based on net thermal value of peat with 10% moisture. Appendix A).

g) Drying cost/million kJ = 383,000/1,022,000,000
= $0.375/1,000 MJ.

2.5.3 Results

In a determination of the real cost of producing peat fuel via a wet mining processing, and including a low severity conditioning of the peat slurry, each segment or component of the peat production system can be segregated and analysed, with respect to its contribution to the overall unit cost of producing a kg of fuel or an MJ of energy. The results of the cost estimates calculated for the construction and operation of a peat fuel drying system, as described in this report, show:

- The capital costs for a drying system module, rated at 50,000 tonnes/yr of anhydrous peat, is $400,000.00, including labour, site erection, and commissioning.

- The combined capital and operating costs of the thermal drying system designed for this project, including depreciation, finance, maintenance, labour, and commissioning, are estimated to be $0.375/1,000 MJ for the fuel produced by this process.

2.6 FIGURES AND TABLES

FIGURES

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3. FINAL SECTION

3.1 CONCLUSIONS

The following conclusions are made from the work performed in this contract.

- A thermal drying system for peat fuel has been designed, which will reduce the water content of the peat fuel from 50% to 10%, by the economic use of waste heat from a peat fuel processing system, and based on the principle of wet mining and low severity conditioning of the peat slurry, previously developed jointly by the National Research Council and the Université de Sherbrooke.

- Based on developed costs for the waste thermal energy of the peat fuel processing system, the cost per 1,000 MJ of processing peat fuel through the dryer, will be of the order of $0.375. In this instance, the inlet fuel moisture content is 50%, and the dryer outlet fuel moisture content would be approximately 10%.

- The capital cost of a peat fuel drying system rated at 50,000 tonnes/yr of anhydrous peat, will be of the order of $400,000.00.

- The overall objectives of the project have been met in terms of a practical design of a peat fuel drying system, which can be made as an integral component of a total peat fuel processing system, within acceptable capital and operating costs, and dewatering capabilities.

- The success of this drying system design means that the most difficult portion of water removal from the peat can be accomplished to the point where the peat fuel will have a heating value of 23,000 to 28,000 kJ/kg (10,000 to 12,000 Btu/lb), which in turn makes the peat fuel processing by the wet mining technology a competitor to existing imported fossil fuels. In this connection, the present cost target for production of peat fuel is $2.85/1,000 MJ, in which the $0.375/1,000 MJ for thermal drying is very acceptable.

3.2 RECOMMENDATIONS

The drying system described in this report assumes that peat fuel will enter the dryer tunnel with water contents of 50%. The basis of the 50% water content arises from the following considerations:

- Peat slurry will enter the peat fuel processing system with a nominal water content of 90%.
- After conditioning of the slurry in the low severity section of the process, the slurry will be mechanically dewatered to bring the moisture content down to between 50 to 70% water, depending upon the efficiency of the mechanical dewatering process.
- If the mechanical dewatering can bring the water content of the peat down to 50%, then direct entry to the drying system is possible, practical and economical.
- If the mechanical dewatering can only reduce the water content to 70%, then further dewatering will be essential, preferably by use of a steam drying system.

From these considerations, plus recent tests on the mechanical dewatering of peat, which have been carried out by others, it would appear that a steam drying system may be required to ensure that the water content of the peat fuel will be of the order of 50% before entering the drying system. Some investigative work would, in that event, be required to establish the capacity and water removal capabilities of a steam drying system, as a part of the total thermal dewatering system of a peat fuel processing plant.

The drying system designed for this project also requires that the peat fuel have a physical form equivalent to small pellets. Uniformity of these pellets is helpful in the semi-fluidized bed conveyor considered in the design, but not absolutely essential. For instance, the tunnel cross-section of the drying system has been deliberately shaped in the form of a trapezoid, wider at the top, to reduce the average drying gas velocity by one half to cater to the possibility of peat fuel dust, in which case the low velocities at the top should ensure that the dust could not be carried to the exhaust parts of the drying system. From this design, the drying system is capable of conveying peat fuel with great variation in physical form and size.

3.2 Recommendations cont.

Given the above scenario, there are, however, limits to this physical variation in the peat fuel which can be dried by the system. For instance, large chunks of peat fuel would not be dried on average to the same water content as equivalent amounts by weight of smaller pieces of peat fuel. In addition, any attempt to use peat fuel for thermal drying as received directly from a mechanical dewatering system, would have the fuel in a form which would be too large to utilize efficient operation of the drying system. The system has been so designed with a specific size, weight and configuration of peat fuel in mind, and the mass transfer of water from the fuel so calculated to ensure sufficient dwell time within the three separate segments of the dryer tunnel to effect the total water removal from the peat as specified.

From the above, it is then recommended that some further work is essential to develop a piece of equipment to take previously mechanically dewatered peat, and make tiny pellets of optimum size and shape for drying.

A final recommendation arising from this work is that a full scale pilot or demonstration peat fuel drying system as described herein, be fabricated, erected, commissioned, and tested as early as possible, in conjunction with a peat fuel processing system, since the drying of peat from 50% to 10% water content is the most cost-effective segment or portion of the entire peat fuel processing system.

3.3 REFERENCES

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3.4 APPENDICES

APPENDIX A

CALCULATIONS OF CALORIFIC VALUE OF WET PEAT, COMPARED TO A NOMINAL 23,260 KJ/KG FOR 100% DRY PEAT

Basis of Calculations:

1. Moisture content is regarded as being heated from 10°C to 205°C and vapourized.

2. Percent of additional excess air required is calculated as equal to moisture content, for example, 10% moisture needs 10% excess air, 50% moisture needs 50% excess air.

3. The excess air is also figured as being heated from 10°C to 205°C.

Typical Mass Ratio of Air/Fuel for Dry Solid Fuels

= 10 kg air/1 kg fuel.

Heat Lost in Excess Air

For each 10% moisture in fuel, add 10% more air.
i.e., 1 kg air/1 kg fuel, sp.ht. = a kJ/kg/°C
Heat loss = 1 x (205 - 10) x 1 = 195.0 kJ

Heat Lost by Warming the Moisture

Sp.ht. (water) = 4.19 kJ/kg/°C Gw = 0.1
0.1 x (100 - 10) x 4.19 = 37.7 kJ

Heat Lost by Vapourizing the Moisture

Heat of vapourization at 100°C = 2,411 kJ/kg
0.1 x 2,411 = 241.1 kJ

Heat Lost by Warming the Vapour

Sp.ht. (vapour) = 2.05 kJ/kg/°C
0.1 x (205 - 100) x 2.05 = 21.5 kJ

Total Heat Losses = 495.3 kJ

Each additional 0.1 kg water uses 495.3 kJ.

Calculations of Calorific Value cont.

TABLE - CALORIFIC VALUE PER 1 KG OF WET PRODUCT

Moisture Content (Wet Basis) %	kg Solids per Total kg	Gross Heat of Combustion kJ/kg	kg Liquid	Deduction from Gross Heat	Net Heat kJ/kg
0	1	23,260	0	0	23,260
10	0.9	20,934	0.1	495	20,440
20	0.8	18,608	0.2	990	17,618
30	0.7	16,282	0.3	1,485	14,797
40	0.6	13,956	0.4	1,980	11,976
50	0.5	11,630	0.5	2,475	9,155

TABLE - CALORIFIC VALUE PER 1 KG OF SOLIDS

Moisture Content (Wet Basis) %	kg Liquid per kg Solid	Deductions	Net Calorific Value
0	0	0	23,260
10	0.1111	550	22,710
20	0.25	1,238	22,022
30	0.4286	2,122	21,138
40	0.6667	3,300	19,960
50	1.00	4,950	18,310

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FACTORS IN THE DETERMINATION OF THE REAL COST OF PRODUCING PEAT FUEL BY A WET MINING PROCESS

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THE VALUE OF WASTE HEAT

To assign any value to a waste seems self contradictory. However, the moment anyone has a use for his own or someone else's waste, then it is not a waste any longer, and the value is determined by mutual agreement.

Assuming that there is a transfer between two parties, the agreed value cannot be any less than what it is worth to the seller, nor any more than it is worth to the buyer. Supply and demand determines where the price will fall in between these two limits. For instance, where the supply is almost infinite compared to a miniscule demand, the resulting price becomes barely high enough to cover the nuisance cost of the transaction. A factory might be paying $4.00 per tonne for waste removal, and then find someone who can use the waste and is willing to accept $3.00 for the service of removing it.

Application of These Valuation Principles in Peat Dewatering From Viewpoint of the Low Severity Treatment Plant

For any use which requires the full temperature range of the available heat, for example, (538°C - 10°C) for high temperature flue gas, the full price of $2.84/1,000 MJ is reasonable. In low end uses, where the heat could be replaced satisfactorily by heat with a lower temperature, the value of the heat is considered as being reduced to the ratio of original value multiplied by temperature range used, divided by temperature range available.

For instance, if hot flue gas were being used for warming a slurry from 10°C to 50°C, it would be making poor use of the available temperatures of up to 538°C. The value for energy in this application becomes:

$$\$2.84 \times (50 - 10)/(538 - 10) = \$0.215/1{,}000 \text{ MJ}.$$

Heat used in a dryer has a range of values, depending on its temperature, with the value increasing all the way up to 538°C (1,000°F). Waste heat, which is available at temperatures far below 538°C, has to be significantly cheaper than primary heat, to compensate for needing a larger dryer.

When a dryer uses waste flue gas at 260°C (500°F), this gas will leave the dryer at 66°C (150°F), leaving no value in the heat at lower temperatures.

Value = value of primary heat multiplied by temperature range used divided by temperature range in heating to primary temperature.
= $2.84/1,000 MJ x (260 - 66)/(538 - 10)
= $1.04/1,000 MJ.

Value of Waste Heat cont.

Consequently, the fair value for flue gas at 260°C can be anywhere between $0.215 and $1.04/1,000 MJ. An assigned value of $0.55 seems reasonable.

Warm Air Obtained From Flash Steam Condenser

Assuming that the processed slurry will have its pressure reduced in steps, then the flash steam will be supplied in at least two different pressures. It is assumed that some of it will leave sufficient pressure for low pressure injection into the raw slurry and the rest will be at close to atmospheric pressure.

This very low grade steam is not needed for slurry heating, because the hot water provided by the filter presses is sufficient for this heating. Consequently, the low pressure steam is almost worthless to the slurry processing system.

- Flue gas, nearly saturated, returning from dryer to slurry heating at 66°C (150°F).

  This gas is of no further use to the dryer, where its value now is 0. It can be used very effectively in heating the slurry at the low end, where its temperature starts at 10°C.

  The value for slurry heating in the range from 10°C to 60°C is $2.84 x (66 - 10)/(538 - 10) = $0.30/1,000 MJ.

  A reasonable price for this transfer is $0.15/1,000 MJ.

- Humid air leaving dryer at 37.8°C.

  This air is of no further use in the dryer but it can be bubbled in the cold slurry to recover its sensible and latent heat. Value to slurry heating is $2.84 x (37.8 - 10)/(538 - 10) = $0.15/1,000 MJ.

  A reasonable nominal value for this transfer of energy is $0.075/1,000 MJ.

  This seems like a very low value. In a less efficient system one might even use full cost primary heat at $2.84 for low level heating. However, there are other costs associated with the use of low grade heat. Further, it is not yet clear whether the slurry system needs all of this low grade heat, so its real value is very low.

  If there is more of this very low grade heat than is needed for slurry heating, the excess will be used in preventing a freezeup of the slurry reservoir. In this application, the reservoir will be kept open for most of the winter, to get maximum yearly output from the dewatering plant.

APPENDIX D

Cost of Flue Gas for Drying

Eg = 13,535 MJ/hr

Calculated fair price for "waste" gas at 260°C (500°F) = $0.55/1,000 MJ.

Energy input to dryer by flue gas = 13,535 MJ/hr x 5,000 hrs/yr.

Yearly cost = 0.55 x 15,535 x 5,000 = $37,221.00.

Waste low grade steam at 100°C, released by the low end of the disentrainer in the slurry processing equipment, is available for condensing to provide warm air at 93.3°C for drying. This heat is of even less value than the 260 C flue gas, say $0.15/1,000 MJ.

Ea = 25,871 MJ/hr.

Cost for a 5,000 hrs/yr operation = $0.15 x 25.871 x 5,000
= $19,403.00

Total Energy Costs for Dryer

Flue Gas	= $ 37,221.00
Warm Air	= $ 19,403.00
Electricity	= $150,000.00
Total	= $206,624.00

Comparison of Energy Costs in a High Temperature Dryer

Quantity of Heat Energy E tot.

To evaporate 8,889 kg/hr using a minimum of 2,500 MJ/kg at $2.84/1,000 MJ, would cost $63.84/hr x 5,000 = $319,215.00/yr for heat.

Such a dryer would have much smaller gas flow rates, reducing the electrical cost to $50,000.00/yr instead of $150,000.00.

Total energy cost is: $319,215.00 + $50,000.00 = $369,215.00

Yearly savings in energy cost by using low cost waste energy = $369,215.00 - $206,624.00 = $162,591.00.